

Wisconsin's Pavement Management System: The Next Generation

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1996

ABSTRACT

Since the late 80's many state and local agencies have developed comprehensive pavement management systems. As these systems mature, it is time to reflect on the effectiveness of the decisions made during those initial developments. The Wisconsin Department of Transportation (WisDOT) has been actively developing the Pavement Management Decision Support System (PMDSS) for nearly a decade. This innovative system was one of the early attempts to develop an expert system for analyzing pavement problems. The system was one of the first to be based on a geographic information system (GIS). Since the introduction of PMDSS, WisDOT has gone through many changes of personnel and policy. Two years ago, a reevaluation and revamping of the pavement management system began. The basic changes in the system that were developed concentrated on providing more information, rather than a single solution, to the user. By providing the user with greater options and background information, greater flexibility and creativity could be achieved while maintaining engineering integrity of selected options. In addition, greater emphasis has been placed on better modeling of various performance parameters. All of these efforts were designed to improve the flexibility of the system in hopes of improving user acceptance.

KEYWORD: Pavement Management, Information System, Expert System

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Pavement management has been an integral part of the Wisconsin Department of Transportation (WisDOT) planning and programming process for many decades. In the 1970's the WisDOT implemented a state-wide ride monitoring program. By the 1980's, the ride monitoring program was augmented with a comprehensive pavement distress (condition) survey. By the end of the decade, WisDOT had a functioning, expert system-based, geographic information system-based (GIS), project-level pavement management system. Developments in the early 1990's aimed at enhancing the project-level analysis with a network-level component. In addition, efforts were made to provide a comprehensive cross section inventory of all current and historic pavement structures. This system, called the Pavement Management Decision Support System (PMDSS), was discussed extensively in Transportation Research Record 1455.

When the system was first introduced, expectations for PMDSS were high. Initial acceptance of the system at WisDOT was good. However, over a relatively short period of time, the system's use began to decline. As with so many things in life, expectations are oftentimes not met. If this pavement management system were to continue to be used and thrive, a serious reevaluation of the basic elements of the system would be needed, and actions would have to be taken to correct problems. This is the area WisDOT has been working on and is the topic of this paper.

What was found, more often than not, was that the technology aspects associated with pavement management were not nearly so daunting as the challenges presented by the organization's attitudes and expectations. Regrettably, there was a significant concentration of efforts (and development) on the "hardware" end (technology, data, models) of the spectrum, while the "people" side (attitudes and ideals) of the issue was not given sufficient attention.

FUNCTIONAL REQUIREMENTS

The first consideration when evaluating an existing system is to ask the simple question -- Is this system doing the job that I expected it to do? In the case of WisDOT's PMDSS, the basic function it was expected to fulfil was that of "decision support". Specifically, the system was to provide the user with a mechanism to analyze pavement treatment strategies, to provide prioritized maintenance and improvement projects, and to provide pavement designers with basic information on structure and performance (past, current and future). To a large extent, PMDSS was successful in providing these functions. Why then, did the system fall into disuse?

Budget and Programming Focus

The main output from the original PMDSS was a prioritized list of potential projects. This list was quite comprehensive and offered several treatment alternatives, which regrettably, were dependent on budget levels. In essence, it produced exactly what the original development group wanted. However, this ended up not being what the actual users expected. Expectations changed between the time the initial specifications were created and actual introduction of the system.

A major shortcoming of the original PMDSS was that the "single solution" produced by the system was viewed as inappropriate for a given discipline. For planning, the syntax of the solution did not match common nomenclature. For designers, detailed information was not provided. For maintenance, options were not available. For example, the system would recommend that a given pavement should have a thin overlay. For planning purposes, this had to be interpreted as requiring a "Resurfacing" project. The designer would want to know what depth the overlay should be. The maintenance supervisor would want to know what would happen to the pavement if some patches were placed rather than executing a full overlay. None of the users were provided the information that they specifically needed. One of the underlying principles of the original developers of PMDSS was to provide consistent decision making. In reality, what the users needed was more diverse information from which they could base their decisions.

Another problem identified involved the logic used in developing PMDSS recommendations. PMDSS was (and still is) based on expert knowledge. The treatment strategies are those that reflect the standards and practice in use. From the very beginning, the expectation was that this system would reflect the decision making processes of the organization. This resulted in a fairly complex system that most users were unwilling to expend the effort to understand. Because of this, users of the system began to view the system as a "black box" solution. This, in turn, led to a general mistrust of the output.

The solution pursued to alleviate these problems was relatively simple. The "covers" needed to be stripped away from the system, and interim reports needed to be developed. Most of the information to "de-mystify the black box" was internal to the system already. In addition, alternate strategies were already part of the system. They were simply discarded by the time the "final solution" was reported. By providing more access to the interim analyses (through reports, charts, maps and tables), the expert system becomes less of a mystery and more a part of the process. By providing direct access to all the alternative treatment strategies, the human once again becomes part of the decision process, and acceptance should be improved.

Network/Project Level Dichotomy

In its original form, PMDSS was basically a project level system with some network capabilities. After its introduction, emphasis in development was made to make the system more of a network analysis system. In Wisconsin, the distinction between a project level analysis is tied directly to the performance attributes of a roadway (cracks, ruts, faults, patches, etc.). The goal of the analysis is to derive a treatment to, potentially, a plethora of problems. The network level analysis dealt with indices (distress and ride) and solutions were derived by a fixed rehabilitation cycle.

When the analysis was run at these different levels, it was not uncommon to have the network level analysis provide one answer, while the project level analysis produced another. In essence the left hand and the right hand were not working together. Interestingly, this also reflected the reality of program and project level development in the organization. It was, and is, not uncommon for planners to budget and schedule a project at a given level of effort and have the designers come in later, and change the basic scope of a project. The system reflected practices.

The answer came from a reevaluation of what was being attempted in pavement management. All of the measurements and indices for a pavement are in essence indicators of performance. In most pavement management systems, parameters of pavement performance are used to develop a ranked list of projects for improvement. These needs are then compared and contrasted against other needs and a program developed.

The approach WisDOT is pursuing is to take a more global view. Rather than indicating a specific solution for a set of conditions, the revised system indicated the appropriateness (is it a good idea to use a treatment) and impact (benefits to increased pavement life) for all possible treatments for a given roadway section. This is based on models of individual distress characteristics as well as gross indices. By doing this, the planner is given more latitude in selecting projects that make sense when all needs are viewed together, while having access to the project level treatment strategies. In this way, the planner can meet policy goals for performance while using the detail provided in a design level analysis. In essence, the distinction between network and project level analysis is meaningless and the two levels can be welded together.

DATA REQUIREMENTS

The life blood of any information system, and pavement management is no exception, is the data upon which performance is measured and models built. Without this, the system is meaningless. WisDOT has a long history of collecting accurate and complete pavement performance data. However, there are some areas where application of the data has proved to be an interesting challenge.

Data Base Design: Elegance verses Use

PMDSS has an elegant data base architecture. It is a GIS based system and the attribute data are stored in relational data bases. This makes for very efficient storage of data, but also limits access to those who have computer skills beyond normal levels found in most civil engineering groups. A number of applications were written against those data bases which, it was hoped, would provide the needed reporting and access capabilities. However, there was always one more way that the user wanted to view the data. This resulted in a plethora of confusing reporting options, inefficient ad hoc query mechanics and unmet needs.

The solution pursued was to provide a "user view" which simplified the data base by removing some of the relational aspects of the data structure. Although this sacrificed some of the inherent efficiencies from a computing standpoint, the new data structure was far more intuitive for the end user. The original design was maintained for purposes of storage and archive of historic data. This has proved to be a highly popular move as most of the users can now have direct access to all data elements and create there own ad hoc reports and statistics.

Logic Update

The original PMDSS system had three levels of analysis. The first level assessed individual distress characteristics (cracks, ruts, faults, etc.) to generate an "attribute problem level". The second step was to assess "pavement problems". In this step, various attribute problems were used to define a specific pavement problem. For example, the pavement problem "Unstable Base and Subgrade" is defined by the attribute problems of "Alligator Cracking", "Transverse Distortion", "Longitudinal Distortion" and "Rutting". Various combinations of these attributes produce various pavement problem levels. The final level of analysis is the selection of treatments to apply to a given set of pavement problems. All of this was developed through expert knowledge.

This has proved to be an excellent method in practice. This technique was maintained during the reevaluation of PMDSS. Some elements have changed. New techniques and practices have been implemented. Because of this, the logic for defining attribute problems, pavement problems and treatment strategies have all been review and updated to reflect these changes in practice.

Improved Performance Modeling

In the original PMDSS, performance modeling was very crude. The system basically modeled one element (ride) and there was only one independent variable (age). This was a particularly incomplete method and identified very early as a problem.

A great deal of effort has been expended on updating the predictive models used by the system. New models have been developed to predict not only indices for ride and distress, but also individual attribute problem levels. The characteristics of the models include some structural elements and regional factors. For example, there are now models to predict the level of each of the distress survey items (transverse cracking, rutting, etc.). In each case the level is dependent on age, region and pavement type. In its original form the system had one deterioration model. Now it has over a hundred models. Although the level of sophistication is still limited, this was a giant step forward.

Inadequacy of Indices

One area that is a continuing problem with WisDOT's pavement management is the use of an index called the "Pavement Distress Index" (PDI). This index is a value derived from the individual distress characteristics for a given pavement. Basically, it combines all of the highly detailed survey data into a single number. This in turn is used as a "trigger" for improvements. This was one of the major elements in the "network level" analysis noted above.

There are several problems with the use of indexes to trigger decisions, and PDI is no exception. First, PDI is sensitive to maintenance activities such as crack filling and patching. In a recent case, a project was planned for improvement in six years. Maintenance undertook an extensive crack filling program. The pavement was surveyed in the next cycle. The PDI improved because previously surveyed severe distress was now covered. The project was out of the program. The pavement still needed repair but was no longer being considered because the PDI had fallen. Blindly following an index and automatic trigger levels resulted in a poor decision.

Second, the PDI is used to trigger planned improvements (in the network analysis). However, the type of improvement is not evaluated with regard to what is actually wrong with the pavement. This is what leads to the problem noted above where planners schedule and budget one type of project and designers find that it is the wrong type of project after it's been investigated more completely.

This problem still exists in WisDOT's pavement management system. However, effort is underway to reduce the use of indices and emphasize the need to use the raw data from the field survey used to define the index.

ORGANIZATIONAL REQUIREMENTS

There is a strong commitment at WisDOT to doing our jobs better. WisDOT has instituted many programs and policies in an attempt to make that possible. However, in some areas, it is proving difficult to make this happen simply because of the way WisDOT is structured.

The 90's have produced some monumental changes in the basic organizational structure of WisDOT. As this article is being written, these changes continue. This has led to some confusion and blurring of roles and responsibilities at WisDOT. This, in turn, has made implementation of the Intermodal Surface Transportation Efficiency Act (ISTEA) management systems difficult.

Seizing the Opportunity

The impetus for developing a pavement management system came from the highest levels at WisDOT. When ISTEA was enacted, this simply emphasized the need for continued effort. When the final product, PMDSS, was produced, it was a radical departure from the practice of the day. The system was based in GIS principles, operated on a UNIX workstation, used relational data bases, and had expert system logic as its base. This was simply too much change for an organization that was still operated primarily from mainframe data bases and using hierarchical processing. This still holds true today.

Today, a great deal of effort is being expended to reduce the differences between the PMDSS system and the classic methods of analyzing pavements. PMDSS is being used to support the classic methods while using the more modern methods. Slowly, the transition is being made into more appropriate solutions.

Making Decisions

WisDOT is a highly decentralized organization. There are eight district field offices that are responsible for all aspects of project development. The central office has responsibility for policy, oversight, specialty engineering functions and support. Because of this "semi-autonomous" structure in the field offices, it is exceptionally difficult to provide a systemic solution when each of the districts has its own idiosyncracies.

This was a serious problem for the original PMDSS. In its original form, the decision making process was very rigid. Although the expert system was based on interviews with representatives of all district offices, some bias was reflected in the system as discrete decisions were required in the end. This, in turn, led to a credibility question in many quarters.

The solution was to eliminate the rigid analysis process and return to basic engineering principles. When the logic for the system was reviewed, there was a great deal of discussion regarding the appropriateness of several treatments for a given problem. In the end, the decision was made to accept any solution, as long as it was based in sound engineering principles. Decisions of cost effectiveness or appropriateness of the treatment for a given set of conditions was left to the user to evaluate. In this way, the preferences of individuals and the realistic difference in various parts of the state could be supported by a system.

User Problems

Any management system, pavements included, can be a complex endeavor requiring a multitude of skills. In the case of PMDSS, it is useful to have knowledge of pavement design, statistics, performance modeling, computers applications, research principles, pavement maintenance routines, and pavement condition survey practices. In an organization that has limited resources and constrained budgets, finding this skill set can be difficult.

When PMDSS was originally rolled out, little guidance was provided to the field offices regarding responsibility for the new item. Each district made it's own decision regarding who would take on this new role. Because of this, approximately eight different approaches were taken. In some districts this function became the responsibility of the pavement designer, in others, planning, and so on. Because of the diversity of needs and knowledge levels, it soon became an impossible task to train and support those responsible for using the tool.

PMDSS is a complex system. Although it has a multitude of menu driven applications, the sheer volume of information that is available and the number of different views that can be taken of the data can be quite perplexing. The level of complexity led many to abandon efforts to use the system.

The final area of difficulty related to the "part time" user. Many of the standard functions that were automated by PMDSS were executed annually, and usually took only a few weeks to complete. Because of this, no one (outside of the development and support resources) was expected to use this system full time. It is perfectly natural for people to forget how to do things when they are done infrequently, and that was the case here.

The solution to the triple dilemma of sparse skill sets, complex functions and infrequent use compelled a rethinking of the roles and responsibilities for using this system. Many of the functions have been and are continuing to be centralized under the development and support resources. Most of the complicated ad hoc functions are being done centrally. As simplified data structures and processes become available, these are being distributed to the field offices.

TECHNOLOGY REQUIREMENTS

The single most unstable and unreliable aspect of any business today is arguably the technology used to do our jobs. Hardware, software, networks, peripherals all conspire to make the task of managing an information system nearly impossible. Couple this with changes in basic data definitions in order to make things "better and easier", and the problems of technology can become very difficult indeed.

Unstable Environment

WisDOT's PMDSS resides on a UNIX platform. The user interface and data structure are handled using Environmental Systems Research Institute's (ESRI) Arc/Info software. Over the years, several in-house custom programs (using C and Fortran languages) have been written to accomplish tasks that were inefficiently executed using Arc/Info processes. Because of this, each time a new hardware platform, software upgrade or operating system change was made, the support resources were compelled to recompile and redistribute all of the custom programming. This quickly became an unreasonable burden.

As with many other organizations, WisDOT and state government in Wisconsin have been forced to confront a very volatile computing environment. For better or worse, all government agencies in Wisconsin are being forced to adopt a single computing platform, operating system, and network for desk top computing. Unfortunately, the mandated system is not the one used by PMDSS.

The only element of the current computing environment that is stable in WisDOT is the use of Arc/Info. Because of this, a great deal of effort has been expended in redesigning data bases and redeveloping system code and user interfaces to all operate under the ArcInfo umbrella. In this way, the system is isolated from the volatility of the hardware, network and operating system problems. This will be a wise direction until the day support for ESRI software is eliminated in Wisconsin.

GIS Base

One of the innovative features in the original and current PMDSS is that it is based on a GIS engine. The historic benefit of this solution is that it allows data and analysis results to be displayed on a map. Important as this is, it is only the tip of the proverbial iceberg. The real power of the GIS engine is that it allows disparate data to be compared, overlaid and analyzed in ways that are very difficult with other methods. The integrating element is the location of the data in space. So long as a data element is in some sort of meaningful topology, it can be integrated in a GIS.

Historically, this has been one of the strongest attributes of PMDSS. More recently, however, changes have been made to the locational references on which the data is based. These foundational elements are critical to the use of a system. When a decision is made to make changes in this type of data, it has monumental consequences on system integrity and data continuity. A great deal of effort is currently under way to insure that the "new and improved" locational reference methods are incorporated into PMDSS.

Better Access Tools

One of the brighter spots in the technology arena is that tools from many vendors are being developed to allow better and easier methods to analyze data. In the not to distant past, it was up to the user or developer to create the tools to provide access to data bases. This precluded a large and potentially valuable group of users from generating their own creative and innovative solutions.

PMDSS, with it's new and simplified data structure, is ideally situated to take advantage of these new tools. One such tool, ArcView from ESRI, is currently being used in conjunction with PMDSS to do ad hoc query, reports and mapping in the field offices and is very popular.

FUTURE DIRECTIONS

There is no system that is perfect. New creative and innovative methods are always being developed that may have appropriate use. This is also true with pavement management. WisDOT is constantly looking for new and better ways to manage its pavements.

Public Perception

One of the areas that has been nearly universally ignored when considering pavement management is the view of the public. For decades (at least since the AASHO road test), engineers have blindly assumed that the decisions that were made regarding pavements were those desired by the people who drove on (and paid for) them. When PMDSS was first developed, the experts that were asked to provide information on how to treat problems were engineering experts. No action was taken to insure that the levels of concern and the actions taken were those desired by the public.

Wisconsin, in conjunction with Iowa and Minnesota DOTs, has begun a comprehensive survey of the driving public to ascertain the desired levels of performance and determine the areas in which the public is interested. The survey is being conducted in such a way that the techniques will be repeatable. In this way, continuous monitoring of public needs can be done.

Upon completion of the initial survey, the results will be incorporated into PMDSS. In this way, good engineering judgement can be used to insure the needs and desires of the public can be met.

Improved Models Using Infrastructure Data

Some organizational elements of WisDOT have made a serious commitment to developing and maintaining a highly detailed data base of all cross section elements. The data base includes information on not only the various width and depth of pavement layers, but details on everything from joint spacing to asphalt types. Also included are all the base, subbase, subgrade, shoulder, and auxiliary lane data. Each record in the data base identifies a unique pavement structure. Each time any variation in any of the cross section elements occurs, there will be a new record. This is a highly detailed data base.

To date, the use for this data has been primarily to enhance preliminary engineering and project scoping efforts. Some research activities have begun regarding overlays and performance of pavements.

These data are a treasure house of potential modeling efforts. On an ad hoc basis, many of the distress manifestations that exist on the highways can be directly attributed to marginal practices in design of the cross section. Currently there is no direct tie between performance modeling and the details of the cross section. WisDOT is making strides to make this link tangible. In the near future, it is hoped that there will be performance models using the specific attributes of the existing and historic pavement structure.

Improved Field Data Collection

With the decentralized organization at WisDOT, data collection for distress surveys are

executed by the district offices. Although generally, this system has worked well to provide accurate data, some inconsistencies do occur. Over the years, a great deal of effort has been expended in training and quality assurance. Regrettably, the results of this effort have not completely solved the problem.

WisDOT is actively pursuing automated data collection devices, especially for distress survey. It is hoped that in the future, automated collection and processing will provide consistent and complete field data acquisition, with ever improving timeliness.

Improved Use of Construction Testing Results

WisDOT has a very comprehensive data base for construction field test results. These data provide a ready information source for the adequacy of materials and construction techniques. Currently, there is no tie between the results of these field tests and performance modeling efforts.

In the future, especially with the use of GIS, it is hoped that this information can be used to refine current performance models.

CONCLUSIONS

The success of a system is dependent on many elements. At WisDOT, the implementation of pavement management through PMDSS has proved to be a difficult task. Although the system originally fulfilled the requirements set forth, expectations changed. With the change in expectation came development that moved in many directions in an attempt to fulfil diverse needs. The result was a comprehensive system that few had the time and ability to use.

Development continues. Efforts are made to improve access to the underlying information. Logic updates and improvement have been made. Continued effort is made to insure data integrity. With this, acceptance is improving.

In order to have a successful implementation of a new system, all issues must be carefully considered. Oftentimes, technological considerations outweigh other considerations. The developer of new systems must constantly strive to avoid this pitfall. Ultimately people have to use these systems. If user needs are appropriately considered, success is assured.